The Boeing Company

TECHNICAL APPENDIX
May 26, 2005

Method for Deriving a Maximum Permissible Power Level for an Individual Airborne Picocell System

Boeing believes that the Commission's rules governing airborne picocell system operations must prevent harmful interference into terrestrial wireless networks under worst-case conditions and using conservative assumptions. This Technical Appendix sets forth an analytical construct for deriving a maximum in-band radiated emissions level for an individual airborne picocell system such that aggregate emissions of all airborne picocell systems would not cause harmful interference to terrestrial wireless networks. Defining maximum permissible emissions for an individual airborne picocell system would create an easily administered and verifiable requirement that would facilitate operation of airborne picocell systems on an unlicensed, non-harmful interference basis without the need for coordination with terrestrial wireless licensees.

I. Airborne Picocell Systems

An airborne picocell system is comprised of the picocell base station and associated wireless devices, as well as interference mitigation measures designed to limit the potential for interference into terrestrial wireless networks. Interference mitigation may be provided by signal attenuation from aircraft fuselage and additional aircraft shielding, control of unsupported handset transmissions and other techniques. In addition, operational procedures including altitude restrictions and other measures limit the potential for interference from airborne picocell operations.

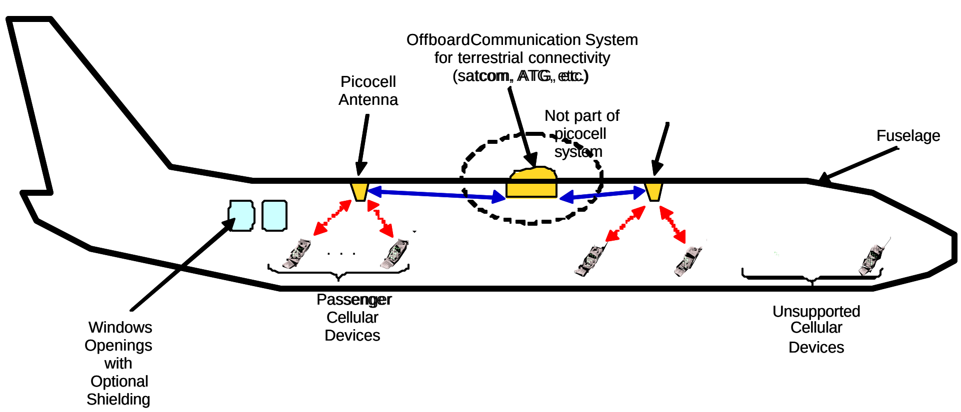


Fig. 1 Example of an Aircraft Picocell System

Although not part of an airborne picocell system, a necessary ancillary component for airborne picocell systems is an off-board communication method. There are wellestablished off-board communication methods that could be used to convey (backhaul) airborne picocell system traffic between the aircraft and the ground, including satellite (*e.g.*, Connexion by Boeing^{SM}) and air-to-ground links (*e.g.*, Airfone).

II. Identification of a Worst-Case Permissible Interference Level

An essential element of defining a maximum permissible power limit for an individual airborne picocell system is identifying a permissible level of interference, under worst-case conditions and using conservative assumptions, from which to work. In a recent proceeding that addressed permissible interference from unlicensed devices, the Commission endorsed a maximum aggregate interference value (rise in receiver noise floor) of 1 dB.[1/]

Based on this precedent and relevant study activities, it is reasonable to define an individual airborne picocell system power limit by requiring that the aggregate emissions of all airborne picocell systems not cause a reduction in the sensitivity (increase in the noise floor) of terrestrial wireless networks of greater than 1 dB.

Because worst-case conditions and conservative assumptions are utilized, the identified level of permissible interference may never be reached even in the most extreme real-world conditions. Moreover, as discussed herein, temporal fluctuations in airline traffic and regional variations in air traffic density confirm that the maximum potential interference from airborne picocell system operations would occur only for short periods of time and in limited geographic regions. At all other times and in all other areas, the potential for interference from airborne picocell system operations is substantially less than the value identified.

III. Minimum Operational Restrictions for Airborne Picocell Systems

Boeing believes certain fundamental operational restrictions must be imposed on airborne picocell system operations to prevent harmful interference into terrestrial wireless networks. At a minimum, these include prevention of direct off-board communications by wireless devices and minimum altitude restrictions.

A. Prevention of Direct Off-Board Communication by Wireless Devices

An airborne picocell system should be designed to prevent onboard wireless devices from directly connecting to terrestrial wireless networks, as shown in Figure 2. When wireless devices connect to the airborne picocell system base station, the power control system forces the handset to an extremely low power state (less than or equal to 1 mW). In contrast, an onboard wireless device communicating directly with a terrestrial wireless network would typically need to transmit at or near its highest power state

[1/] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, 18 FCC Rcd 3857, ¶ 77 (2003) ("*UWB Order*") (rejecting arguments that a 1 dB increase in the noise floor of a mobile receiver is indicative of harmful interference).

(typically 500 mW). In addition, direct off-board communications by wireless devices are difficult to manage because it is possible for a device to "see" a large number of terrestrial base stations from an airborne aircraft. For both of these reasons, direct off-board communications by wireless devices onboard aircraft in flight can cause harmful interference to terrestrial wireless networks and must be avoided.

Fig. 2 Illustration of Onboard and Offboard
Connectivity to Wireless Devices

Boeing believes that airborne picocell systems should be designed to prevent direct off-board communications of supported wireless devices (those using technology compatible with the onboard picocell) and to force unsupported wireless devices into a quiescent state in which they do not transmit. With respect to the latter requirement, Boeing notes that wireless devices that do not operate in U.S. commercial mobile radio service ("CMRS") spectrum in the 800 and 1900 MHz bands will assume a quiescent state because there will be no compatible terrestrial wireless network with which to communicate when flying over U.S. territory.

Various solutions to prevent direct off-board communications by wireless devices are being examined in various forums (*e.g.*, RTCA, WAEA and ECC). Reducing the signal-to-noise ratio ("SNR") of the forward link signal being received by onboard wireless devices from terrestrial networks is one method to prevent off-board communication. Below a threshold SNR level, the wireless device will stop transmitting because it is out-of-range of the base station. By reducing the signal level (*e.g.*, attenuation from the aircraft fuselage or additional shielding) and/or increasing the noise level in the aircraft cabin (*e.g.*, using RF management units), the SNR can be reduced below the threshold at which the cellular device can receive the forward link transmissions from terrestrial base stations.

This will prevent unsupported wireless devices from transmitting and thus force them into a quiescent state. Supported handsets, on the other hand, will establish communications with the airborne picocell system and be commanded to transmit at their lowest power levels given their proximity to the picocell base station.

B. Minimum Altitude Restrictions

Additional reduction in potential interference from airborne picocell systems into terrestrial wireless networks results from path loss and atmospheric attenuation associated with providing wireless services on aircraft in flight. Boeing believes that the Commission's airborne picocell system rules should reflect the Federal Aviation Administration's ("FAA's") requirement that all portable electronic devices ("PEDs") (including wireless devices) be turned off and stowed below an altitude of 10,000 feet. Of course, most commercial aircraft cruise at an altitude substantially higher than 10,000 feet and the actual effects of operating airborne picocell systems at higher altitudes may be taken into account in deriving permissible operating parameters.

IV. Derivation of a Limit on Individual Airborne Picocell System Radiated Emissions

Given the starting point of 1 dB maximum rise in total noise to any terrestrial cellular receiver under worst-case conditions and using conservative assumptions, it is possible to derive a requirement on maximum radiated emissions from an individual picocell system such that the total noise floor rise from all airborne picocell operations (*i.e.*, emissions from all picocell-equipped aircraft within the radio horizon of a terrestrial wireless receiver) is =1 dB. Note that the following discussion of an appropriate analytical construct for deriving such a limit represents Boeing's preliminary analysis and is intended to generate additional discussion in the context of this proceeding so that the Commission can adopt appropriate technical requirements for airborne picocell system operations.

Airborne picocell system operations can raise the noise floor of both terrestrial base transceiver stations ("BTS") as well as wireless handsets. Boeing believes that the Commission should consider only the case of interference into BTS receivers because this is the limiting case. Cellular handset receivers are not as sensitive as BTS receivers (handsets have noise figures of 8-9 dB instead of 3-5 dB for BTS receivers).

The geometry of potential interference from airborne picocell systems into terrestrial wireless BTS receivers is shown below.

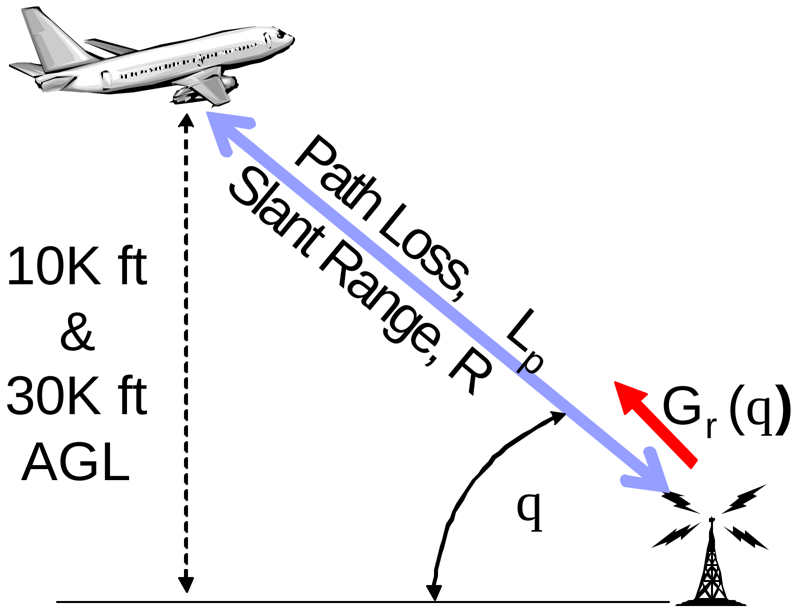
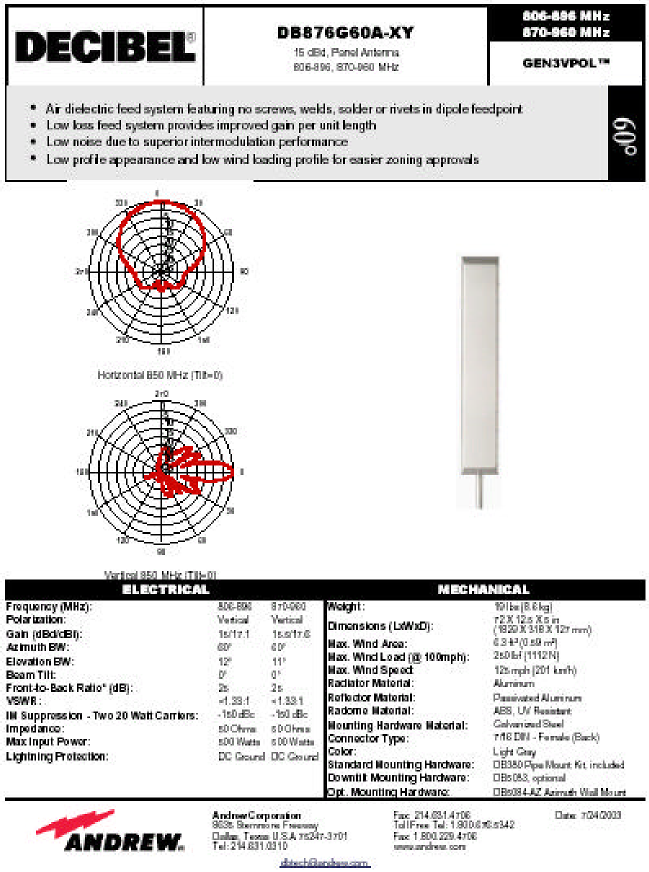


Fig. 3 Geometry of Interference

A number of factors affect the derivation of a limit on individual picocell system radiated emissions. These include: (i) BTS receive antenna gain in the direction of airborne picocell system transmissions and slant angle; (ii) path loss associated with altitude effects; (iii) atmospheric attenuation; (iv) aircraft attenuation; and (v) the aggregate impact of multiple picocell-equipped aircraft. Each of these factors is discussed separately in the following subsections.

A. BTS Antenna Gain in the Direction of Airborne Picocell System Transmissions and Slant Angle

There are hundreds of different BTS antennas in use throughout the United States operating at different frequencies, polarizations and azimuthal beam widths. Boeing has studied the gain characteristics of a wide range of different antenna designs (high gain panel antennas, omnidirectional antennas, etc.). A typical high gain 800 MHz panel antenna (Andrew Corp. DB876G60A-XY) providing a narrow 60 deg (6-sector) azimuthal beamwidth is shown in Figure 4.



DECIBEL®

DB876G60A-XY
15 dBd, Panel Antenna
806-896, 870-960 MHz

806-896 MHz
870-960 MHz
GEN3VPOL™

- Air dielectric feed system featuring no screws, welds, solder or rivets in dipole feedpoint
- Low loss feed system provides improved gain per unit length
- Low noise due to superior intermodulation performance
- Low profile appearance and low wind loading profile for easier zoning approvals

60°

ELECTRICAL		
Frequency (MHz):	806-896	870-960
Polarization:	Vertical	Vertical
Gain (dBd/dBi):	15/17.1	15.5/17.6
Azimuth BW:	60°	60°
Elevation BW:	12°	11°
Beam Tilt:	0°	0°
Front-to-Back Ratio* (dB):	25	25
VSWR:	<1.33:1	<1.33:1
IM Suppression - Two 20 Watt Carriers:	-150 dBc	-150 dBc
Impedance:	50 Ohms	50 Ohms
Max Input Power:	500 Watts	500 Watts
Lightning Protection:	DC Ground	DC Ground

MECHANICAL	
Weight:	19 lbs (8.6 kg)
Dimensions (LxWxD):	72 X 12.5 X 5 in (1829 X 318 X 127 mm)
Max. Wind Area:	6.3 ft² (0.59 m²)
Max. Wind Load (@ 100mph):	250 lbf (1112 N)
Max. Wind Speed	125 mph (201 km/h)
Radiator Material:	Aluminum
Reflector Material:	Passivated Aluminum
Radome Material:	ABS, UV Resistant
Mounting Hardware Material:	Galvanized Steel
Connector Type:	7/16 DIN - Female (Back)
Color:	Light Gray
Standard Mounting Hardware:	DB380 Pipe Mount Kit, included
Downtilt Mounting Hardware:	DB5083, optional
Opt. Mounting Hardware:	DB5084-AZ Azimuth Wall Mount

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Fig. 4 Example BTS Antenna at 800 MHz

The manufactures of BTS antennas usually provide data on G_r(?). The vertical gain pattern, G_r(?), has a narrow 12° main lobe (full width) and side lobes that are about 15 dB down. However, as shown in Figure 5, the vast majority of potentially interfering airborne picocell systems within the radio horizon of the BTS antenna will be at very low elevation angles and thus within the main beam of the BTS antenna.

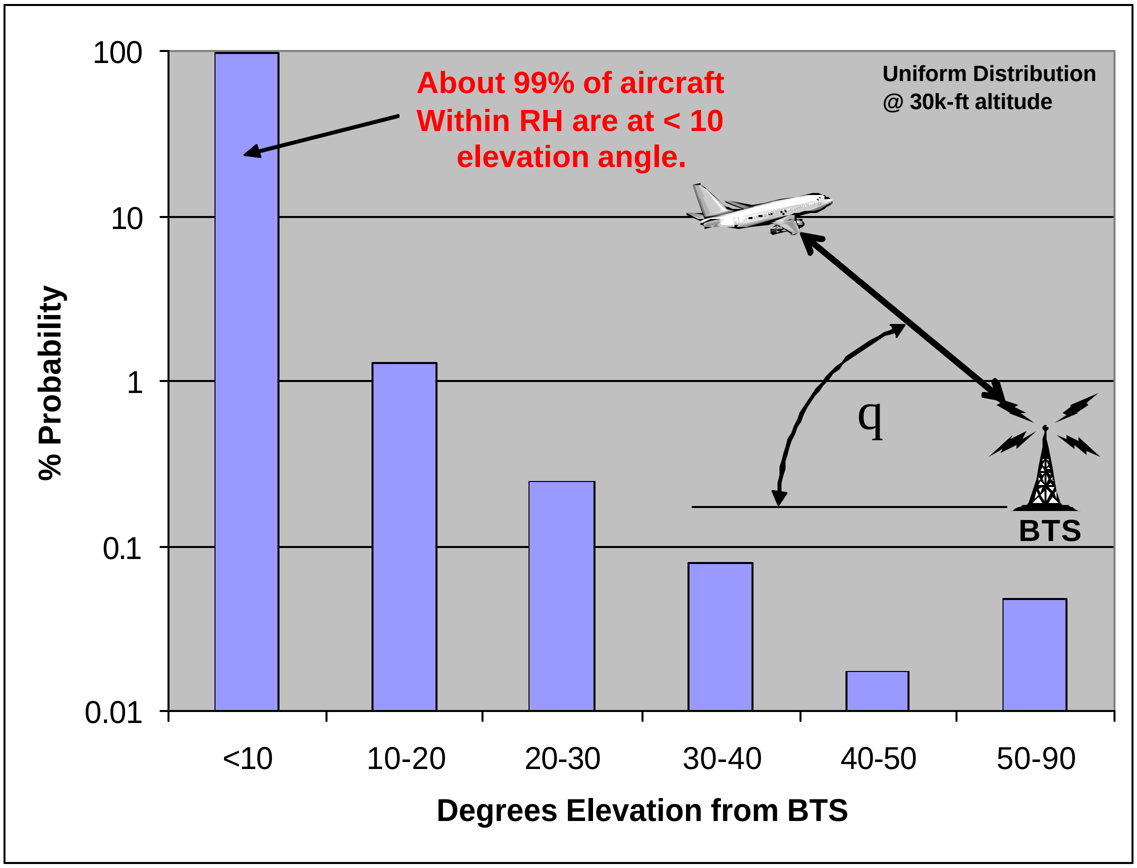


Fig. 5 Distribution of Elevation Angles to Uniformly Distributed Aircraft as Seen from BTS

Accordingly, as a conservative assumption, the highest gain of the BTS antenna is considered. Note that this approach ignores the effect of the down-tilt of BTS antennas, making it even more conservative.

Of course, not all picocell-equipped aircraft will be at low elevation angles relative to the BTS antenna. Some will be at higher elevation angles and even directly overhead. In such circumstances and assuming a constant altitude, the path loss associated with slant range decreases but so does the antenna gain. Boeing believes that path loss and BTS antenna gain can be considered together because they effectively cancel each other out.

A BTS antenna with no down-tilt projects its maximum gain, G_r, towards the horizon (?=0°) and its gain rolls off as the elevation angle, ?, increases. Likewise, the path loss, L_p, is maximum at ?=0° where the slant range is highest, and then decreases at higher elevation angles. By dividing L_p by G_r we get a quotient that is more or less constant over ?, as shown in Figure 6. The lower green curve is the elevation gain pattern G_r(?) for the antenna shown in Figure 4, and the blue curve is the path loss, L_p(?). The red curve is L_p/G_r (or L_p - G_r in dB). There are variations L_p/G_r as a function of ? caused by the lobes of the antenna, but the worst-case dips are at approximately the same value.

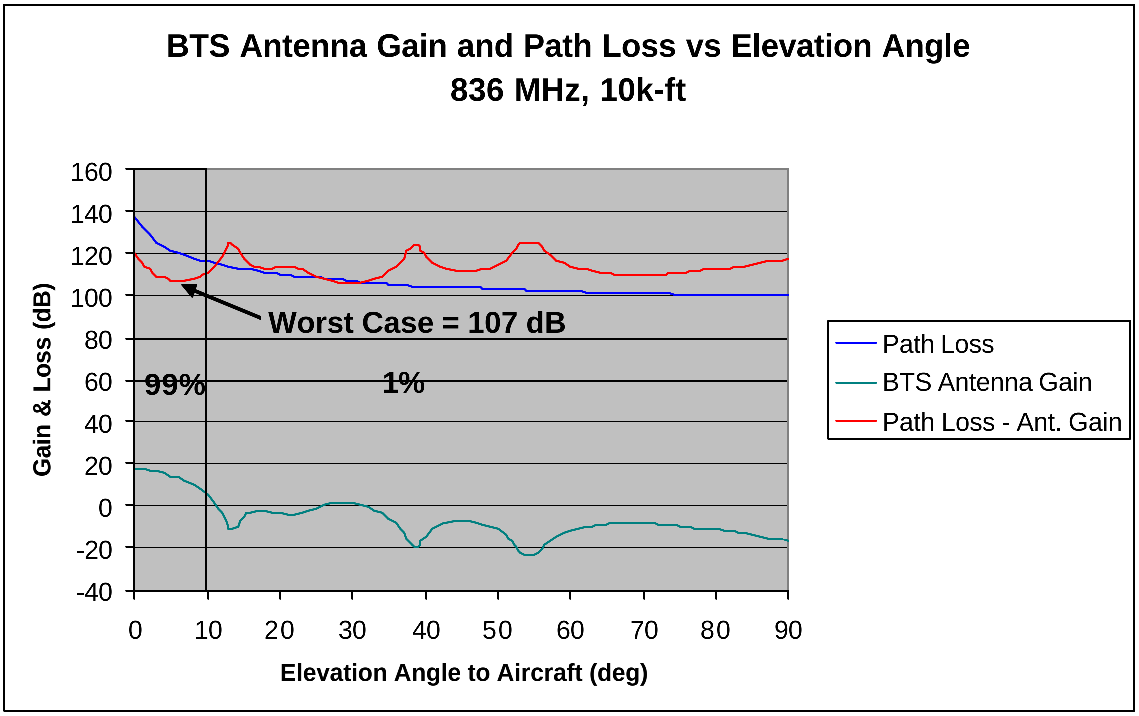
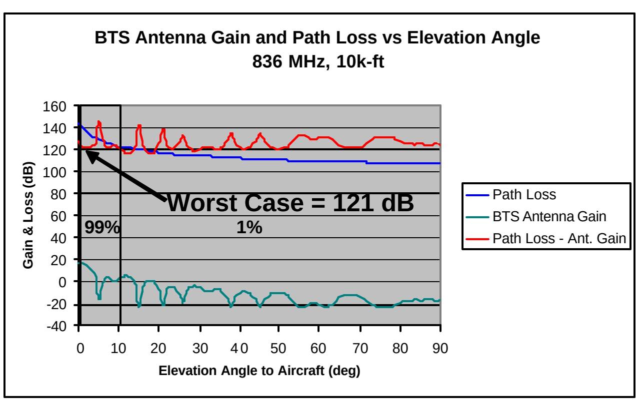
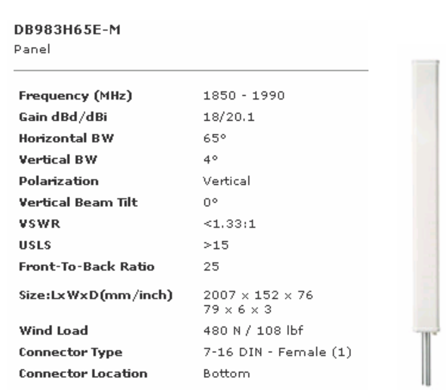


Fig. 6 Path Loss and Antenna Gain as a Function of Elevation Angle for High Gain Panel Antenna in the 800 MHz Band

The preceding analysis was repeated at 1900 MHz using a typical high gain (20.1 dBi) panel antenna (Andrew Corp. DB983H65E-M) optimized for operation in this band. The results for L_p/G_r are shown in Figure 7. As expected, L_p/G_r is higher at 1900 MHz because of the increased path loss at the shorter wavelength.





DB983H65E-M
Panel

Frequency (MHz)	1850 - 1990
Gain dBd/dBi	18/20.1
Horizontal BW	65°
Vertical BW	4°
Polarization	Vertical
Vertical Beam Tilt	0°
VSWR	<1.33:1
USLS	>15
Front-To-Back Ratio	25
Size:LxWxD(mm/inch)	2007 x 152 x 76 79 x 6 x 3
Wind Load	480 N / 108 lbf
Connector Type	7-16 DIN - Female (1)
Connector Location	Bottom

Fig. 7 Path Loss and Antenna Gain as a Function of Elevation Angle for High Gain Panel Antenna in the 1900 MHz Band

The preceding results for L_p/G_r are summarized in Table 1. Considering that most cellular handsets operate in either the 800 MHz or 1900 MHz bands, the PCS band might be the best choice for aeronautical picocell systems because it provides higher L_p/G_r.

Frequency Band	L_p/G_r
800 MHz	107 dB
1900 MHz	121 dB

Table 1. Summary of results for L_p/G_r at 10,000 Feet

As previously noted, there are many different types of BTS antennas in use today. Boeing examined a wide range of different types of antennas, including omnidirectional antennas, which are common in rural regions, as well as 3-sector (120° azimuthal beamwidth) and 6-sector antennas (60° azimuthal beamwidth), and antennas having azimuthal beamwidths less than 60°. For brevity and to pursue conservative assumptions, Boeing has chosen to show results for two of the highest gain antennas in use today because they represent the worst-case by projecting maximum gain at low elevation angles (where most potentially interfering aircraft are located).

B. Path Loss Associated With Altitude Effects

An analysis of potential interference from aggregate airborne picocell system operations must account for altitude affects. As noted above, Boeing proposes that airborne picocell systems should not be permitted to operate below 10,000 feet above ground level because current FAA regulations mandate that all PEDs be turned off and stowed below this altitude. As a result, the L_p/G_r terms identified above for the 800 MHz and 1900 MHz band for aircraft at 10,000 feet are worst-case values.

However, most commercial aircraft cruise at an altitude substantially higher than 10,000 feet and are at lower altitudes for brief periods during climb and descent. Thus, the L_p/G_r term for aircraft at higher altitude will be larger given the greater path loss associated with longer slant range.

Cruise altitudes vary considerably by region and by flight itinerary. However, it is possible to take actual altitude effects into account in deriving airborne picocell system operating parameters by examining the number of aircraft at various altitudes. Boeing is in the process of evaluating aircraft traffic altitude information to provide additional information on path loss associated with altitude effects.

C. Atmospheric and Terrain Attenuation

Because the vast majority of aircraft visible within the radio horizon of a BTS receiver are located at very low elevation angles, the slant ranges to potentially interfering aircraft are quite long. As a result, not only does path loss reduce the potential for harmful interference into BTS receivers, so do atmospheric absorption and terrain blockage effects along the signal path. This is particularly true for aircraft at cruise altitude, which routinely fly above the cloud cover, and at the extremes of the radio horizon.

Boeing is evaluating available information on atmospheric and terrain effects to provide a conservative estimate of these effects in the derivation of an individual airborne picocell system power limit.

D. Aircraft Attenuation

Boeing's preliminary work with airborne picocell systems and general testing of aircraft radiofrequency ("RF") attenuation, as well as that of other investigators, indicates that the radiated emissions from an airborne picocell system will be attenuated by the aircraft itself, as shown in Figure 8, with deep nulls in the radiation patterns in the fore and aft directions, as well as below the aircraft. This is due to the fact that there are no window openings in the fuselage to allow RF energy to escape (note that the cockpit windows usually contain transparent conductive coating for deicing purposes which also act as an RF shield). The sides of the aircraft radiate the most RF energy because the passenger window openings face in these directions.

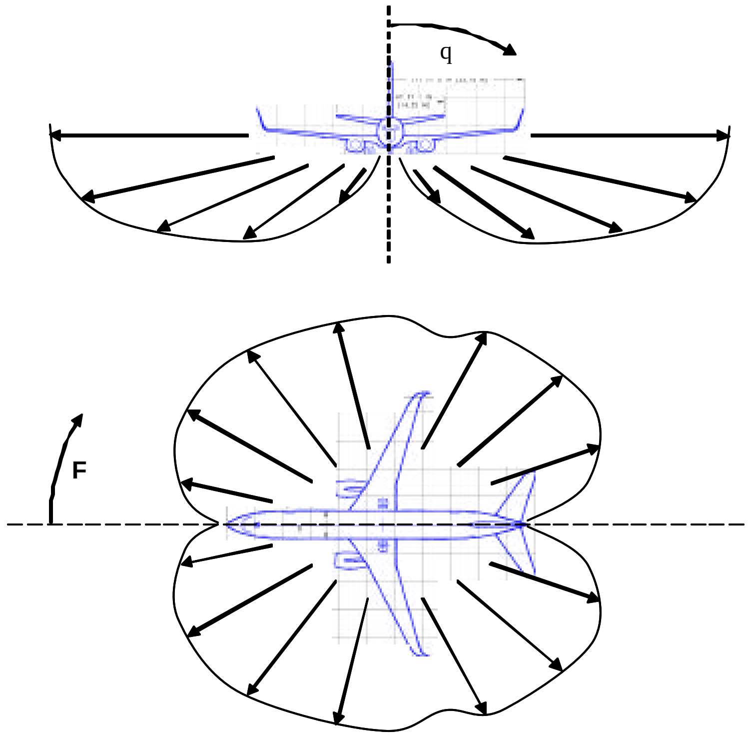


Fig. 8 Example of Radiated Emissions from an Airborne Picocell System

The potential angle range for interference estimation is below the plane of the aircraft wings (?=90° to 270°) and in all directions around the aircraft heading (?=0° to 360°). However, not all of these angles are equally relevant in the context of estimating aggregate interference into a BTS receiver.

As noted previously, more than 99% of all aircraft within the radio horizon of a BTS receive antenna are at elevation angles of 10° or less. As a result, more than 99% of all base stations are seen by the aircraft at ? angles within a narrow 10° range below the wings, as shown in Figure 9.

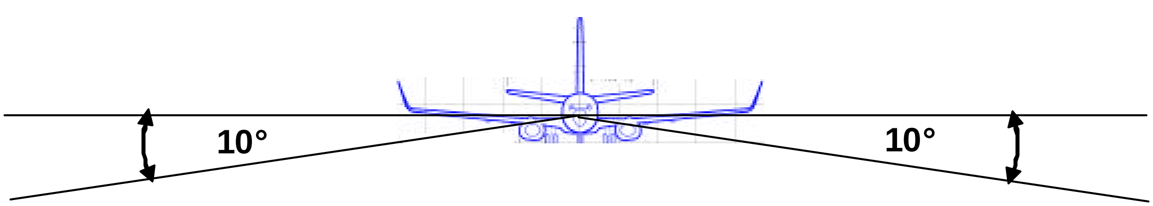


Fig. 9 Most Relevant Angular Range of Radiated Emissions from Aircraft

Of course, at angles greater than 10° below the plane of the wings, attenuation increases dramatically due to the absence of windows. Thus, Boeing believes that evaluating aircraft attenuation within a 10° range below the wings would provide a conservative estimate of aircraft attenuation effects in deriving a maximum emissions limit for individual airborne picocell systems. Boeing is in the process of evaluating test data regarding aircraft attenuation at 800 MHz and 1900 MHz and will provide additional information regarding this factor in subsequent comments in this proceeding.

Boeing believes, however, that given the large number of aircraft that could be located within the radio horizon of a BTS receiver under worst-case conditions and the likelihood that the relative headings, F, of those aircraft towards any BTS will be uniformly distributed over all F, the average aircraft attenuation over all F should be used by the Commission to derive an individual airborne picocell system emissions limit.

In this connection, the red circle in Figure 10, below, is an example of the averaged radiated emissions over all F for a picocell system installed on Boeing's test and demonstration aircraft CBB-1 (737-400).

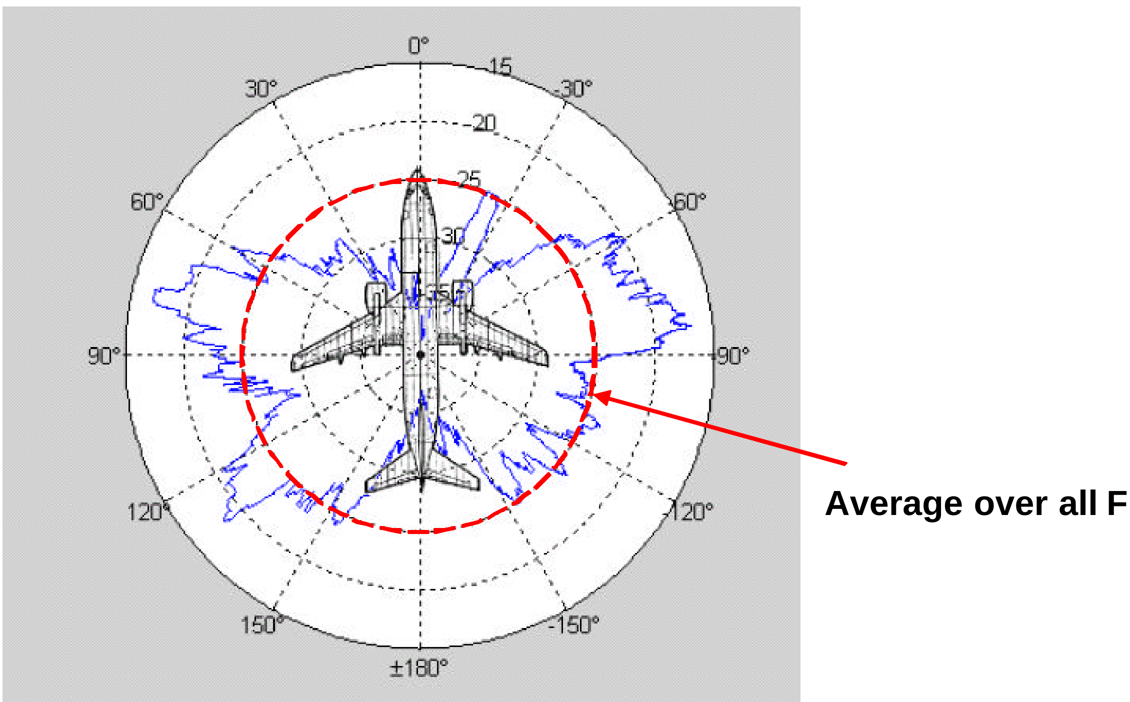


Fig. 10 Ground Measurement of Radiated Emissions from a Picocell System

There is a strong basis to argue that aircraft attenuation averaged over all F should apply. The densest distribution of BTS antennas typically occurs in areas with the greatest population densities, which is where airports also tend to be located. Thus, the worst-case potential effects of airborne picocell system operations (highest density of picocell-equipped aircraft, highest number of potentially affected BTS receivers and lowest altitudes -- *i.e.*, below 10,000 feet during take-off and landing) occur in these densely populated regions when an aircraft is heading towards and away from an airport.

From the relative perspective of a stationary BTS receiver, an aircraft heading towards or away from the BTS will present its nose or tail, which have significantly higher attenuation (Figure 10). Furthermore, even if a BTS receiver is located at an angle perpendicular to the aircraft's heading, it will be located in that region for a short period of time relative to the period it may be located to the fore or aft of the aircraft (just as a stationary object that is passed by a car traveling along a straight road spends much more time toward the front and rear of the car, relative to the short time it is located toward the side). Thus, using an average of aircraft attenuation over all F is a very conservative approach.

Boeing examined a database of FAA radar flight tracks to confirm this approach.[2/] Boeing analyzed a worst-case BTS location near Chicago O'Hare airport and measured the relative headings of all aircraft within the radio horizon of the BTS over a one-week period. The results, shown in Figure 11, demonstrate that the distribution is not at all uniform and show a strong bias towards fore and aft relative headings.

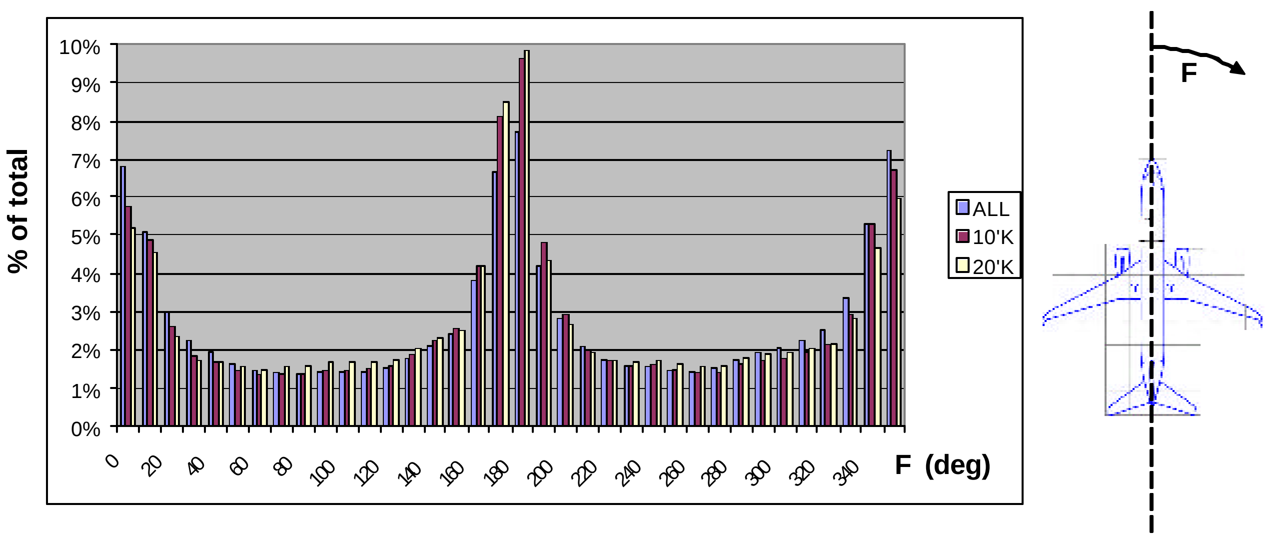


Fig. 11 Distribution of Aircraft Relative Headings to a BTS Located O'Hare

Boeing also examined the relative heading distributions for more rural areas away from major hubs. Figure 12 shows the measured relative heading distribution to a BTS located south of Denver Airport at 39ºN, 104ºW. The traffic around this location is a mixture of cross country flights traversing the busy corridor between the Northeast and Southwest continental United States, as well as some traffic heading to and from Denver Airport. It also shows a bias toward fore and aft headings.

[2/] Aircraft Situational Display to Industry (ASDI), a service provided by the FAA.

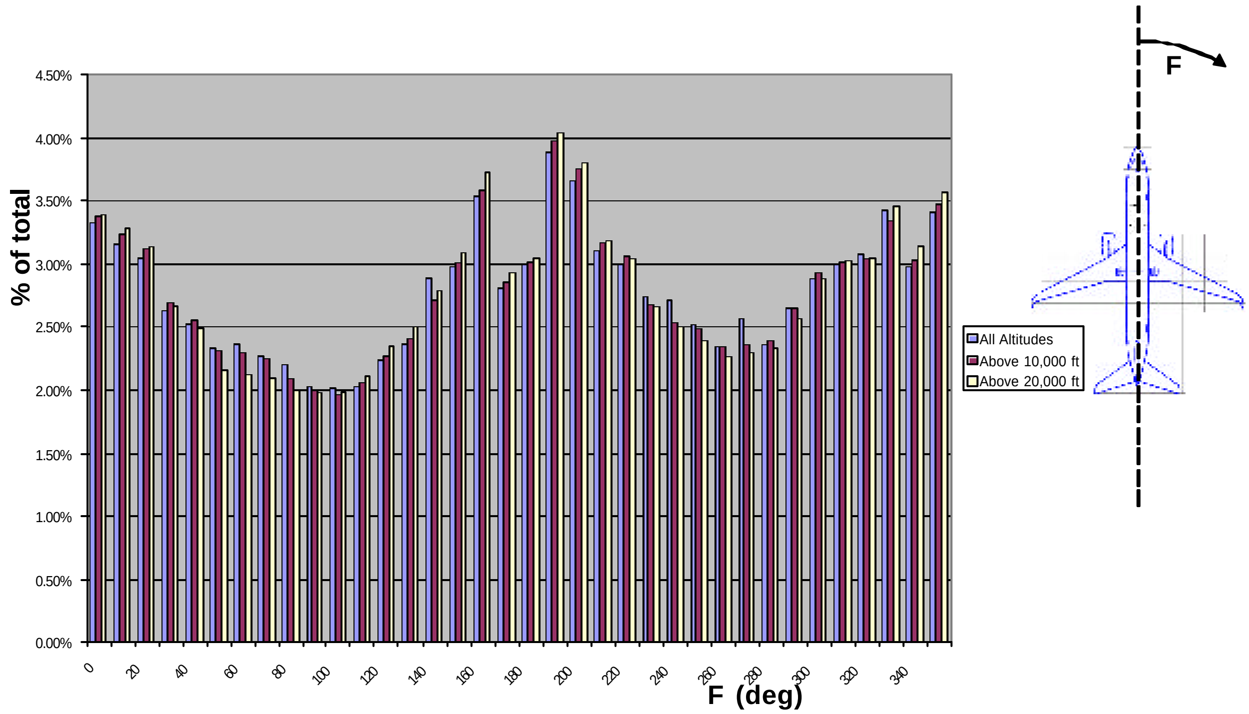


Fig. 12 Distribution of Aircraft Relative Headings to a BTS Located at 39ºN, 104ºW

Finally, Boeing performed an analysis to measure the relative headings distributions from all aircraft to a uniform grid of base stations located across the continental United States. Boeing expected to see a perfectly uniform distribution, but Figure 13 also shows a slight fore/aft bias.

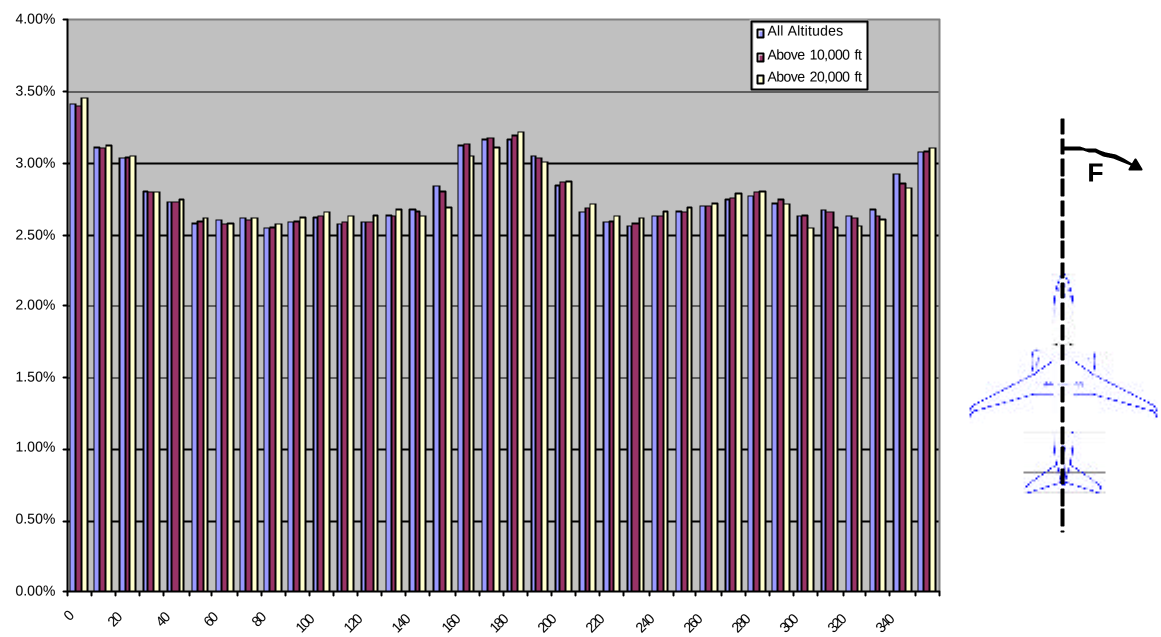


Fig. 13 Distribution of Aircraft Relative Headings to BTSs
Located on a Uniform Grid Across CONUS

The data and analyses support the conservative assumption of uniformly distributed aircraft relative heading towards base stations. Since the average radiated emissions over all F is greater than the radiated emissions in the fore and aft directions (see Figure 10), the use of average aircraft attenuation is a conservative assumption.

E. Multiple Aircraft Factor

1. Maximum Number of Aircraft within the Radio Horizon

Deriving a limit for individual airborne picocell system emissions requires estimating the maximum number of picocell-equipped aircraft within the radio horizon of any BTS. Boeing examined the question of the gross number of aircraft within a BTS radio horizon using the previously referenced database of FAA radar flight tracks over the continental United States. The database was filtered for aircraft having =100 seats, which Boeing believes is the primary market for airborne picocell systems.

The analysis sought to identify the maximum (worst-case) number of aircraft within the radio horizon of 50 feet high BTS antennas distributed throughout the United States. One week of data was analyzed (12/5/04 – 12/12/04) to account for day-to-day variations as well as diurnal variations. Figure 14 shows the results of Boeing's analysis.

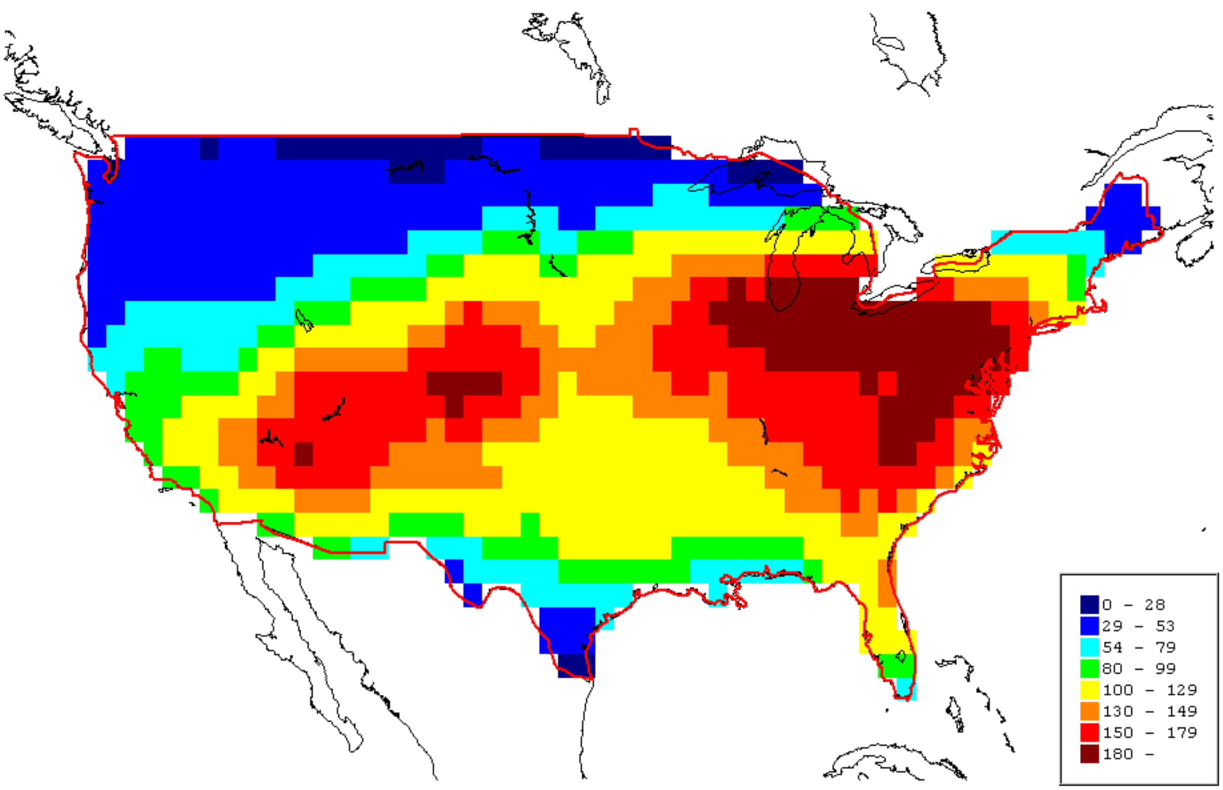


Fig. 14 Maximum Number of Aircraft within the Radio Horizon of BTSs throughout CONUS

There is a maximum of just over 180 aircraft (depicted by the color brown) within the radio horizon of BTSs in regions of the Northeast, Midwest and a small region around Denver. Significantly, Boeing's analysis assumed a smooth earth without any terrain blockage or other attenuating effects. This is a worst-case assumption because terrain variations and other blockage tend to reduce the radio horizon and hence the number of interfering aircraft.

To better understand temporal variations in aircraft traffic, Boeing also examined a specific worst-case BTS location near Chicago O'Hare. Figure 15 shows the variation in the number of aircraft within the radio horizon over a one-week period.

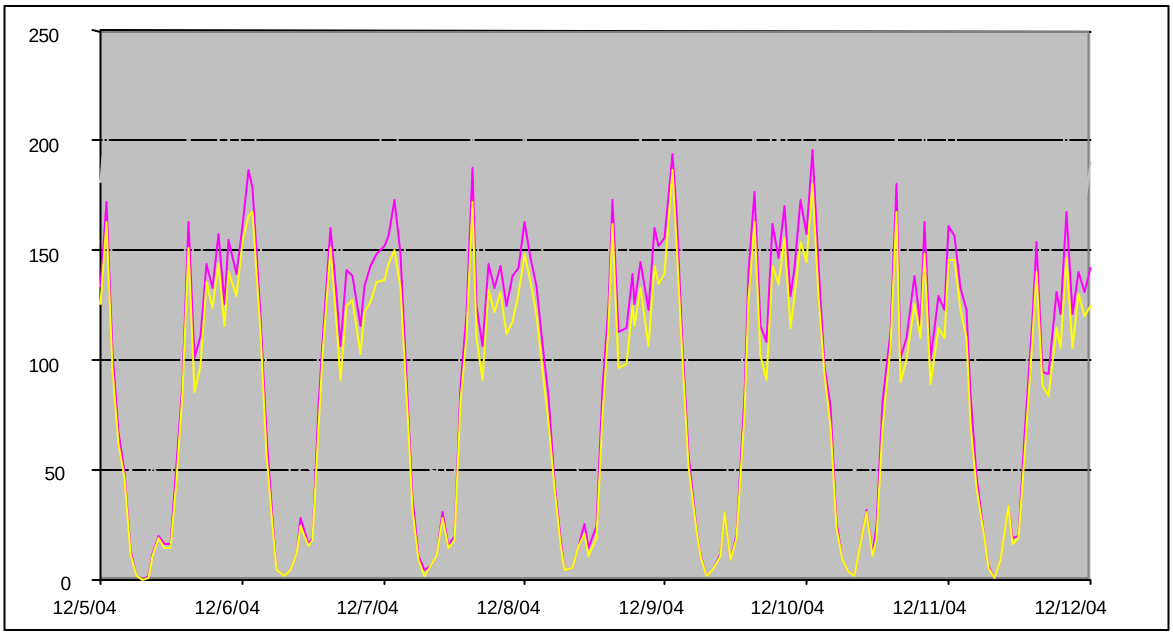


Fig. 15 Temporal Variation of Aircraft within RH of a BTS located near O'Hare

The magenta curve is for aircraft above 10,000 feet, and the yellow curve is for aircraft above 20,000 feet. A statistical summary of the data in Figure 15 is shown in Table 2.

	10K Feet	20k Feet
Mean	92	83
90%	162	148
99%	190	175
100%	192	185

Table 2 Statistics for Number of Aircraft within
Radio Horizon of BTS Located at O'Hare

There are a number of important conclusions that can be drawn from Figures 14 and 15. First, the worst-case maximum number of aircraft within the radio horizon of a BTS occurs within a limited geographic area. Throughout the remainder of the country, which comprises the large majority of the continental United States, the maximum number of aircraft is substantially less. Second, even in the worst-case regions, there is substantial temporal variation in the maximum number of aircraft with short-term spikes evident. Thus, using a value for the gross maximum number of aircraft within the radio horizon of BTS within a worst-case region that is less than the 100% value would still be a conservative assumption for deriving an individual airborne picocell system emissions limit.

2. Number of Picocell-Equipped Aircraft within the Radio Horizon

Although the analyses described above identify a gross maximum number of aircraft within the radio horizon of a BTS receiver, not all visible aircraft will be equipped with airborne picocell systems. Accordingly, the Commission should include a "market penetration" or "deployment" factor in deriving a limit on individual airborne picocell system emissions.

Initially, there will be limited airborne picocell system deployment, with penetration to increase over time as airborne picocell systems, as well as off-board communications systems, are installed on aircraft. Thus, only a fraction of the gross total number of visible aircraft should be considered in defining an individual airborne picocell system limit.

The picocell-equipped aircraft value should be initially set at a conservative level to protect terrestrial wireless systems from interference, and conceivably could be increased over time in direct proportion to the increased number of airborne picocell systems deployed. This would decrease the limit on maximum emissions from an individual airborne picocell system over time but, as explained in Boeing's comments, the introduction of handsets with Wi-Fi capabilities and the potential reduction of GSM minimum power levels would similarly reduce emissions from airborne picocell system operations, making it possible to meet lower limits.

3. Aircraft within BTS Sector

The interference noise into a BTS receiver will be proportional to the number of picocell-equipped aircraft within the radio horizon of the BTS antenna beam. In its survey of BTS antennas, Boeing found that the highest gain BTS antennas had the narrowest azimuthal beamwidth, and the widest azimuthal beamwidth antennas (omnidirectional antennas) had the lowest gain. The gain of the BTS antennas examined was generally inversely proportional to their azimuthal beamwidth. For example, reducing the beamwidth of an antenna in half generally results in 3 dB higher gain.

The higher the antenna gain, the narrower the beamwidth, and the fewer picocell-equipped aircraft within the field of view of the BTS receiver antenna. Thus a 60° beamwidth (6-sector) BTS antenna can only see 1/6th of the total number of aircraft within the radio horizon. Similarly, a 120° beamwidth (3-sector) BTS antenna would see 1/3rd of the total picocell-equipped aircraft and an omnidirectional would see all picocell-equipped aircraft within the radio horizon. As was the case with the slant range and antenna gain calculations, this effect of adding gain yet reducing the number of aircraft visible results in essentially a static figure. Thus, the multiple aircraft factor essentially remains constant in the context of sectorized antennas.